it is on the telescope, represents the percentage of light transmitted by the objective and correcting lens.

To eliminate any error due to variation in the intensity of the sky-light with changing hour-angle of the Sun, the exposures were made in this way: One on telescope, three off telescope; one on telescope, three off telescope; one on telescope.

The effect of diffraction at the slit is to allow light outside the cone of aperture equal to that of the objective to fall upon the collimator-lens when the spectrograph is off the telescope. Any error due to this was shown, by another series of experiments in which a slit of .0006 inch was used, to be very small. In the present experiments the effect of diffraction at the slit is negligible, as a relatively wide slit was employed.

It was possible to detect a two per cent variation in the intensity of the photographic images. From the mean of ten plates an exposure of fifty-one seconds with the spectrograph off the telescope was found to give the same image density as one-hundred-seconds exposure with spectrograph on the telescope. The loss by absorption and reflection of rays λ 4500 at the 36-inch objective and correcting-lens is then forty-nine per cent. Assuming the loss at the correcting-lens to be about ten per cent, this value agrees very well with that calculated above for the 36-inch lens.

Lick Observatory.

THE LOSS OF LIGHT BY DIFFRACTION AT A NARROW SLIT.

By J. H. Moore.

In the design of astronomical slit-spectrographs, where the source of light is in general faint, the question of utilizing as much of the light as possible becomes of fundamental importance. The particular problem for which the instrument is intended will require a certain resolving power and dispersion, which in a prism-spectrograph will correspond to a definite and unavoidable loss of light by absorption and reflection at the prisms and lenses.

To obtain the required purity of spectrum it is necessary

to use a slit of small aperture, at which an additional loss occurs, due (1) to the diminished area of the image source, and (2) to diffraction at a narrow slit. This loss at the slit depends upon the linear slit width, while the purity of the spectrum depends only upon the angular aperture of the slit, as seen from the center of the collimator-lens. It is evidently possible, then, to preserve the purity and at the same time avoid some of the loss at the slit, by employing a collimator of sufficient focal length and aperture, and a slit of greater linear width. The importance of this principle in the design of astronomical spectrographs was first pointed out by Professor CAMPBELL.*

The loss of light by diffraction at a narrow slit, for the region of spectrum $\lambda = 1.8\,\mu$ and for slit-widths from 0 to 0.5^{mm}, has been investigated by Professor ABBOT† in his bolometric researches in the infra red spectrum of the Sun. For the region of spectrum and slit-widths employed in line of sight-work no data are available for the loss by diffraction at the slit, and with a view to supplying these the present investigation was undertaken.

In spectrographic work we are interested in photographic intensities. A photographic method of comparing relative intensities from slits of different apertures was therefore selected. The spectrum of a constant source of light was photographed, using a slit-width .002 inch and thirty seconds exposure. This was taken as giving a standard image density. To obtain the relative intensity due to any other slit-width, say .001 inch, a graduated series of exposures was given with this width of slit. An exposure of sixty-six seconds for a slit .001 inch gives the same image density as that of our standard. The photographic intensity due to a slit .001 inch is taken as being proportional to thirty sixty-sixths the photographic intensity due to a slit .002 inch. Any slight error due to the assumption that the density of a photographic image is proportional to the product of the exposure-time and intensity of the incident light is not effective in the present experiments.

The Mills spectrograph, mounted upon the 36-inch refractor, was directed toward the region of the sky 90° North

* W. W. CAMPBELL, The Mills Spectrograph of the Lick Observatory. *Astrophysical Journal*, Vol. VIII, 1898.

† Annals of the Astrophysical Observatory of the Smithsonian Institution, Vol. I, 1900

Declination and hour-angle six hours away from that of the Sun. The telescope was driven by the clock in order to eliminate the effect of the variation of the plane of polarization of sky-light with reference to the plane of the instrument. In this way a source of light was obtained which was found to be fairly constant when the hour-angle of the Sun was not greater than one hour. To guard against the effect of any variation in the sky-light, the exposures were made in this way (say for a slit .001 inch),—slit .002 inch 30 seconds exposure; slit .001 inch and 63, 64, and 65 seconds exposure, respectively; slit .002 inch and 30 seconds exposure; slit .001 inch and 66, 67, and 68 seconds exposure; slit .002 inch and 30 seconds exposure. It is possible to detect a five per cent variation in the image density by such a method of comparison.

In the following table are given the exposures from the mean of five plates for different slit-widths required to produce the same image density as that from a slit .002 inch and 30 seconds exposure, for the region λ 4500 (the center of the Mills spectrogram). The last column gives the percentage of loss by diffraction for slits of different aperture on the assumption that no light is lost by diffraction at a slit of .004 inch and that the exposure-time varies inversely at the slit-width.

Slit-Width in .001 Inch.	Time of Exposure in Seconds.	Percentage Loss by Diffraction.
4.0	13.0	00
3 5	15.0	00
3.0	17.5	4
2.5	22.0	8
2.0	30.0	13
1.8	34.5	15
1.5	42.5	18
1.4	45.0	19
1.3	49.5	20
1.2	55.0	22
1.0	66.0	24
0.9	77.0	25
0.8	86.5	26
0.7	103.0	28
0.6	134.0	35
0.5	172.0	40

From the above it will be seen that the loss by diffraction increases very rapidly for slits of linear aperture less than

.0007 inch. On the assumption that the light incident upon the slit is parallel, it can be shown that for a slit-width .0007 inch the width of the principal maximum of the diffraction pattern is equal to the diameter of the collimator-lens, (the constants of which in the Mills spectrograph are, focal length $= 722.4^{mm}$, effective aperture $= 38^{mm}$). A further decrease in slit-width will throw part of the principal maximum off of the collimator-lens, causing a rapid decrease in the intensity of the light.

A comparison of ABBOT's results with those given above will show his values for the loss by diffraction at a narrow slit to be relatively much greater than the ones obtained in the present experiments. A little consideration, however, will indicate the cause of this discrepancy (aside from the fact that the wave-length employed by him is four times that used in the present work) is due to the difference in the angular aperture of the collimator in the two instruments. ABBOT used a collimator of angular aperture of about one fifth that of the Mills spectrograph. We should therefore expect the loss by diffraction in his experiments to be relatively much greater than that obtained here.

With the Mills spectrograph, in line of sight-work, a slit of linear aperture .0013 inch is found to give sufficient purity. Now a collimator-lens of twice the diameter and focal length of the present one (neglecting the increased absorption of such a lens) would theoretically enable us to utilize about 2.3 times as much light, as we should then be able to double the slit-width.

On the other hand, the corresponding effective diameter of the collimator-lens would be about three inches. It is very doubtful whether it is advisable to use larger prisms than are employed in the present instrument, for several reasons. To mention only one, such prisms by their greater absorption would reduce greatly the increase of light gained in the above manner.

The substitution of a reflection grating for the prisms may be possible, but here we encounter the difficulty of mounting a reflection-grating so that it cannot move and at the same time not be cramped. Also, since for a reflection-grating there is no position of minimum deviation, a displacement of the

grating produces a corresponding shift in the lines of the spectrum.

We may use a Cassegrainian reflector of great relative focal length and a collimator-lens of small linear aperture. However, for average seeing the image would be larger for the instrument of greater focal length, and while we should gain some light, the gain would not be proportionate.

The telescope and spectroscope of greatest efficiency will be those in which the best compromise is made between the various opposing factors; and this will depend to a considerable extent upon the class of work for which the instrument is intended.

Lick Observatory.

VARIABLE STAR NOTES.

By Rose O'Halloran.

V Cassiopeiæ.

When first discovered in December, 1893, by Dr. Anderson, of Edinburgh, *V Cassiopeiæ* was supposed to be a temporary star, but further observation showed that it ranged from about seventh to twelfth magnitude in a period of 229 days. Though in a field thickly strewn with small stars, it may be found without circles by means of two stars of sixth magnitude with which it forms an obtuse triangle. These are numbered 1 and 2 in Flamsteed's catalogue, the variable being about half a degree northeast of the latter, or in R. A. $23^h\ 7^m\ 22^s$, Decl. $+59^\circ\ 8'\ 4''$. Near the date of predicted maximum, August 15th, it was observed as follows:—

1904.

July 10. Brighter than any of the closely adjacent stars. Equal to *c*.

July 15 and 17. Equal to *d*, less than *b*.

July 30. Brighter than *b*.

July 31. Ditto. Night very clear.

August 1 and 11. Brighter than *a*, which is the brightest of the numerous stars about one third of a degree to the northeast. *V* seems fully of 7.5 magnitude, but is less than star of 6.8 magnitude to the west.